

## North Carolina A&T State University, Greensboro, NC



The Army Reserve Officers' Training Corps program at A&T is made up of a broad cross-section of college students. That's because A&T hosts Army ROTC for all colleges and universities in the greater Greensboro area. This includes, Bennet College, Guilford College, Greensboro College, and the University of North Carolina at Greensboro. Elon College is an extension center of the NCA&T Army ROTC program. Reserve Officers' Training Corps is an elective course. Its subjects include principles of management, leadership development, national defense and military history.

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**LOGANEnergy Corp.**

**Initial Report...FY'02 CERL PEM Demonstration Program**

**North Carolina A&T State University PEM Project**

**Campbell Hall Combined Services ROTC Building, Greensboro, NC**

**April 28, 2003**

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## **Introduction**

Fuel Cells convert the chemical energy of a fuel into useable electric and thermal energy without an intermediate combustion or mechanical process. In that respect, they are similar to batteries. However, unlike batteries, fuel cells oxidize externally supplied fuel and therefore do not need recharging. Ever since National Aeronautics and Space Administration (NASA) adopted fuel cell power for the Apollo Space program, American industry has been fascinated by the prospects for their use on earth as well.

When integrated with a fuel processor and a solid-state power conditioner, the power system becomes one that produces clean, quiet and reliable electric power and heat. Several manufacturers are currently hard at work to translate the basic technology into consumer products. As advances in PEM technology and mass production converge to introduce competitively costs systems into the marketplace, many are betting that small scale fuel cell generators will soon be ready to tackle thousands of residential and small scale commercial power applications. These new appliances will be packaged energy systems providing both heat and electricity that will be able to operate with or without the local utility grid.

Until recently, however, the promise of fuel cell technology has been slow to advance beyond a narrow beachhead commonly referred to as the "early adopter" marketplace. Broader market appeal has been constrained by fits, false starts and premature expectations raised by eager manufacturers; but also high prices, skepticism, and not a little resistance by parochial interests have all restricted the opportunity. Notwithstanding, during the decade of the 1990s, the UTC PC25C Fuel Cell program, largely assisted by a significant investment by DOD, gradually established a solid record of achievement and customer satisfaction at numerous US locations and around the world. Installations sites included military hospitals, commercial buildings, banks, food processing facilities, data processing centers, police stations, and airports.

While many of these "early adopters" hosted pure technology demonstration projects, the industry gained valuable experience and knowledge because of them. More recently, however, customers have warmed to the proposition that fuel cells have real performance advantages in various combined heat and critical power applications (CHP). Perhaps their attitudes and business practices may be adjusting to accommodate an uncertain energy landscape. Clearly, many energy providers are scrambling to maintain their market base, others are floundering, and still others are stalking new opportunity. Nevertheless, they are all discovering that informed consumers have gained new leverage through the power of choice. Increasingly, newspaper articles, periodicals and other media outlets are

scoring direct hits with stories about fuel cells. Policy makers are out front raising expectations of a cleaner highly efficient fuel cell/hydrogen based economy of the future. The signals are clear. Initiative and momentum are driving a rapidly maturing fuel cell industry.

Certainly one reason is because fuel cell technology represents, perhaps, the most exciting and innovative development in the energy industry today. In some ways the technology is maturing more rapidly and markets are developing more quickly than the supporting infrastructure, codes and standards are able to accommodate. However, as technology demonstrations increasingly give way to CHP fuel cell installations that provide practical solutions to demanding consumer requirements, such roadblocks should get resolved as consumer and utility interests find common ground. For example, in most applications, large-scale fuel cell installations may off-load significant power resources during critical grid demand intervals, serving utility interests, while providing "hot" back-up for mission essential loads in commercial and even residential applications. Additionally, they may also provide thermal Btus for heating and cooling loads-demonstrating the dual benefits of enhancing grid stability and promoting energy conservation.

At the small scale and residential end of the fuel cell spectrum, the opportunity is just as promising for the rapid expansion of distributed power generation. Conceivably, thousands of 3kW to 5kW CHP fuel cells in homes and small businesses across the country could within several years displace hundreds of MWhs of electricity and millions of thermal Btus with clean, efficient and reliable energy service. If this occurs, it could have a dramatic impact on both the energy industry, and on the nation's economy and security. Consumers, not utilities, could begin displacing environmentally disruptive generation methods, thereby forcing changes in the industry. As providers of grid resources, they may one day collectively enhance grid stability in many areas, boosting efficiency and conservation norms, and having a decided impact on the evolution of national energy policy.

Against this backdrop, the US Army Corps of Engineers, Construction Engineering Research Lab (CERL) has contracted with LOGANEnergy through its FY'02 PEM Demonstration Program to engage a progressive fuel cell energy strategy to inform future DOD policy and planning. Broadly speaking, this engagement directs LOGAN to purchase and install residential and small-scale fuel cell power plants, and then test and evaluate their performance in widespread applications at selected military installations. Three seemingly incongruous events make this program very timely. They are (a) the complexities and perplexities of utility deregulation juxtaposed with, (b) base utility privatization programs, and (c) the nascent interest in distributed generation / CHP technologies that promise more efficient utilization of resources.

If the fuel cell industry appeared very much ahead of a languid power market in the recent past, today those markets are in comparative turmoil. Prices and availability, in some cases, are volatile and beyond the comprehension of energy managers and consumers alike. Consumers who are seeking innovative and efficient energy solutions for greater comfort, convenience and reliability are adding a new urgency. If the fuel cell industry can capitalize on these conditions, it will have a rich market opportunity, but it will have to deliver energy services and benefits that are immediate, site specific, cost effective, energy efficient, and certifiably green!

In order to test and evaluate the state of PEM fuel cell technology against these challenges, LOGANEnergy Corporation will demonstrate over the course of a year a PEM small scale fuel cell at North Carolina Agricultural and Technology State University in Greensboro, NC. The project will be guided by an operations plan that will direct the installation, testing, evaluation and reporting on the performance of the unit. The objectives of the plan include;

1. Evaluating installation methods in order to help standardize safe and cost effective installation practices,
2. Evaluating "out of the box" reliability and interoperability with existing facility electrical and mechanical systems / infrastructure,
3. Evaluating actual PEM operating characteristics as compared to manufacturer representations,
4. Measuring the cost of operating a PEM unit under real market conditions,
5. Measuring, collecting and analyzing operating data including, total load hours, availability, kW production, fuel consumption, water consumption, forced outages, serviceability, and manufacturer's support.
6. Introducing PEM technology, power distribution and energy efficiency to DOD and local stakeholders in the community.

The project will be led by LOGANEnergy and supported by the NC A&T Energy Technology Center, the university facility's engineering department, by Plug Power and Energy Signature Associates.

## **North Carolina Agricultural and Technological University PEM Site Selection and Installation**

In March 2002 LOGAN contacted Dr. Harmohindar Singh, Director of the Energy Research Center at North Carolina State Agricultural and Technical University in Greensboro, NC to discuss siting a CERL Small Scale Residential PEM Fuel Cell project at the ROTC facility there. As a result of the conversation, Dr Singh invited LOGAN to visit the campus in April 2002 to make a PEM fuel cell presentation to ROTC professors and staff. LOGAN proposed that the installation site would be both novel and instructive for the benefits of engineering students and faculty alike. University officials agreed with the plan. Thereafter, LOGAN proposed the NCA&T ROTC site, Campbell Hall, in its FY'02 PEM submittal to CERL.

In December 2002 the site was awarded to LOGAN and the installation began in late February 2002. [Figure 1](#) and [Figure 2](#) are photos of the fuel cell on its pad at the Campbell Hall ROTC building.



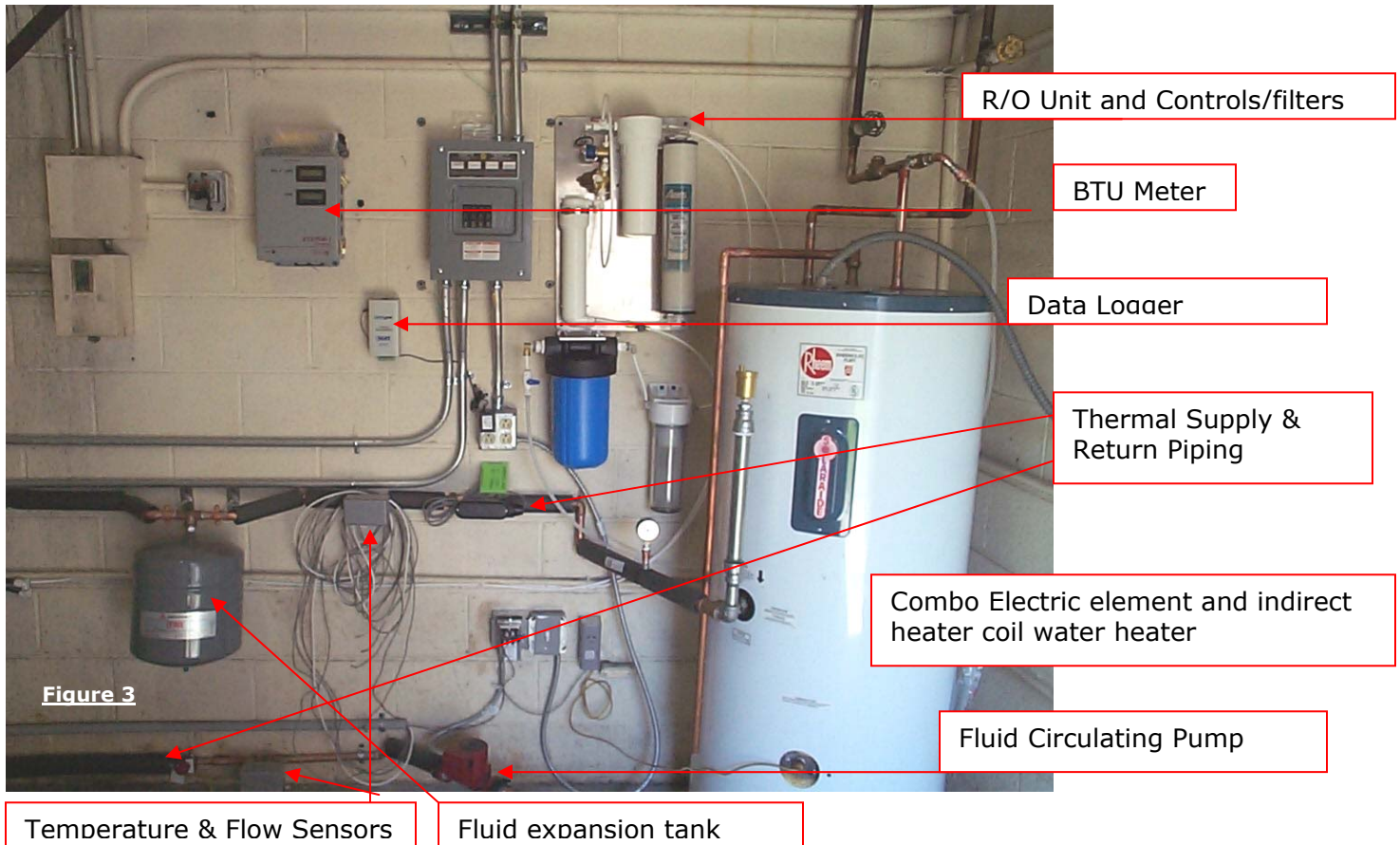
The site provides a significant opportunity for the program, as it places an operating PEM fuel cell on a major southern university operating on a commercial grid system owned by Duke Power. The installation site occupies a very visible presence in a green space between the ROTC building and a student cafeteria. A 300 foot natural gas line was installed by Piedmont Natural Gas.

In [Figure 2](#), at right, another view of the installation, shows the fuel cell against a backdrop of the Marshall ROTC Building. The fuel cell was rigged onto the pad with the assistance of a commercial fork truck. The mechanical room is conveniently located behind the adjacent brick wall. The photo also shows the natural gas meter at left and the electrical interface at right.





Figure 3 below is a photo of the equipment and instrumentation installed to support the thermal recovery plan.



The thermal recovery system is designed to try to optimize the installation by capturing waste heat from the fuel cell and transferring it to a hot water storage tank for distribution within the building. The current design being tested at NC A&T represents both a design and cost improvement over the first such installation at Ft. Jackson, SC. The new hot water tank is a combination electric coil and external heat transfer coil unit manufactured by Rheem. The R/O unit in the picture provides deionized water for the fuel cell stack hydration and cooling. The BTU meter provides a continuous output of heat transferred into the thermal recovery system. The data logger receives 30 second interval pulse inputs from the natural gas meter, the watt meter, and the BTU meter, and records the date and time of these events.

# NC A&T Installation Line Diagram

## Campbell Hall ROTC Center

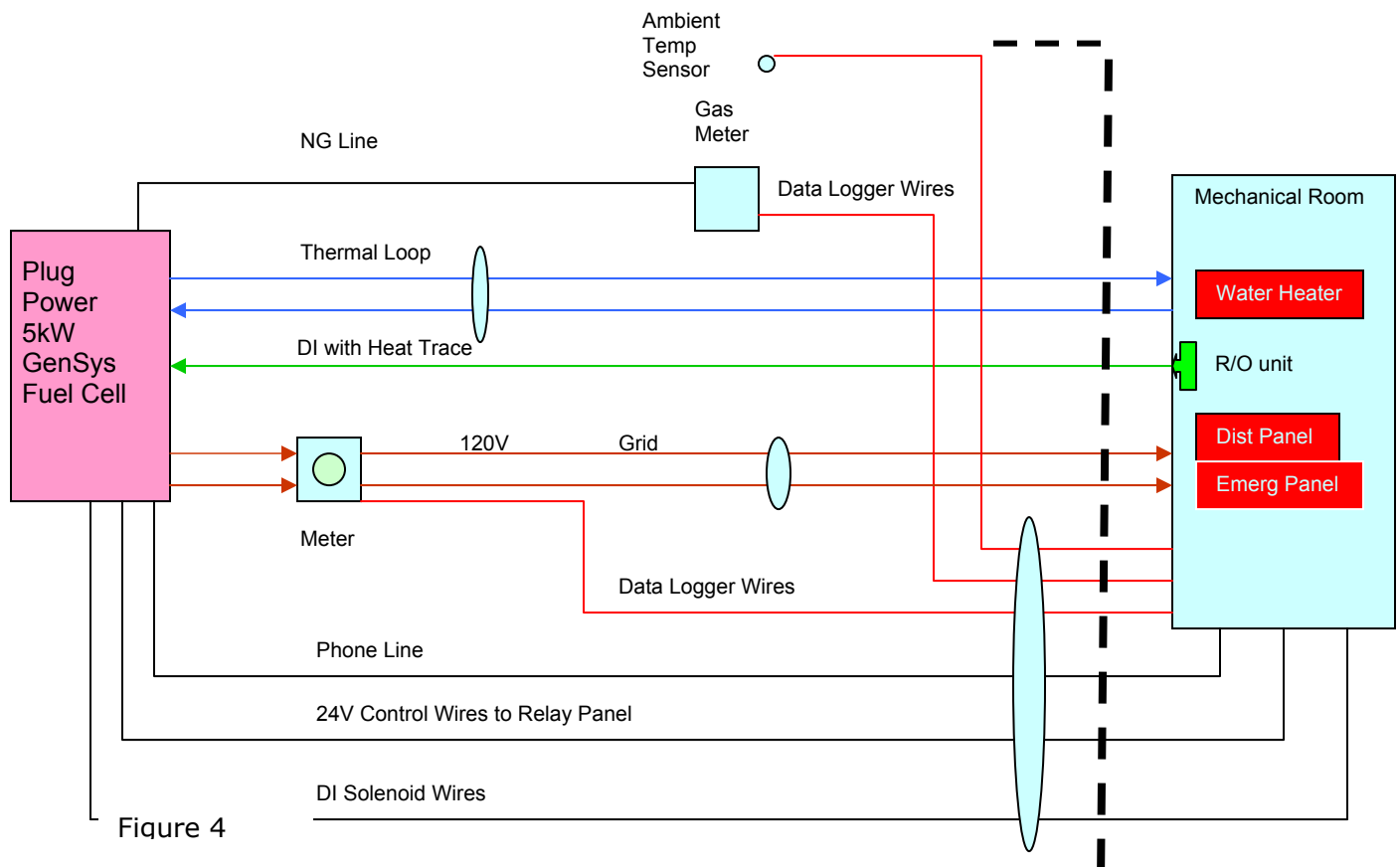


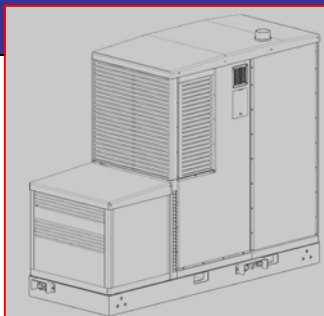
Figure 4



## GenSys5C Product Specifications

### Plug Power Fuel Cell System

The GenSys5C is a 5kWAC on-site power generation system fueled by natural gas. Designed to be connected to the existing power grid, the 5C is a clean and efficient source of power.



## Specifications

Physical	Size (L X W X H):	84 1/2" X 32" X 68 1/4"
Performance	Power rating: Power set points: Voltage: Power Quality: Emissions:	5kW continuous 2.5kW, 4kW, 5kW 120/240 VAC @ 60Hz IEEE 519 NO <sub>x</sub> < 5ppm SO <sub>x</sub> < 1ppm Noise < 70 dBA @ 1meter
Operating Conditions	Temperature: Elevation: Installation: Electrical Connection: Fuel:	0°F to 104°F 0 to 750 feet Outdoor/CHP GC/GI Natural Gas
Certifications	Power Generation: Power Conditioning: Electromagnetic Compliance:	CSA International UL FCC Class B

### Dimensions

Length	84 inches
Width	32 inches
Height	68 1/4 inches

### Operating Requirements

Fuel Type	Natural Gas
Temperature	0 degrees F to 104 degrees F

### Outputs

Power Output	5kW
Voltage	120/240 VAC @ 60Hz
Noise	< 70 dBA@ 1 meter

### Certifications

CSA International	Fuel Cell System
UL	Power Conditioning Module

Figure 5

## **Installation Application**

Figure 4, above, diagrams the fuel cell installation with utility interfaces including, power and water in the adjacent mechanical room of Campbell Hall. Figure 5, above, lists the specifications of the Plug Power GenSys5C PEM technology demonstration fuel cell chosen for this site. Since natural gas was not immediately available to Campbell Hall, Piedmont Natural Gas of North Carolina provided matching funds of \$10,500 to run a natural gas supply line approximately 300 feet to supply the fuel cell. The electrical conduit runs to facility load panels from the fuel cell are approximately 100 feet. The Reverse Osmosis/DI water tubing run that provides filtered process water to the power plant is approximately 30 feet distance, and the thermal recovery piping runs are also approximately 30 feet from the fuel cell; both may also be seen Figure 4 above. The water heater is a 74 gallon Rheem combination electric and heat coil unit that has replaced the former electric unit. Fuel Cell waste heat should be adequate to meet the domestic hot water demand of the facility. Figure 4 also indicates the location of an Onicon BTU meter on the thermal recovery system that will record the waste heat utilization by the facility. Data logging will be accomplished with an Ultralite Logger also indicated in Figure 4 above.

The fuel cell inverter has a power output of 110/120 VAC at 60 Hz, matching the building distribution panel in the mechanical room with its connected loads at 110/120 VAC. The installation includes both a grid parallel and a grid independent configuration as indicated in Figure 4. The unit provides stand-by power to a new 100amp critical circuit panel that serves plug loads throughout the facility. A two-pole wattmeter monitors both the grid parallel and grid independent lines to record fuel cell power delivered to both the existing panel and the new critical load panel installed in the building.

After Piedmont stubbed the natural gas supply at the fuel cell, LOGAN installed a gas meter adjacent to the fuel cell pad as indicated in Figure 4 and seen in Figures 1 and 2 above. A regulator at the fuel cell gas inlet maintains the correct operating pressure at 14 inches water column.

A phone line connection with the fuel cell modem provides communications with Plug Power and LOGAN customer support functions.

## **Permitting**

LOGAN contacted the North Carolina Department of Health and Natural Resources to inquire of the need to apply for an air quality permit to operate the fuel cell. Since the unit's emissions are less than 5 tons per year it qualified for the small generator exemption under in accordance with NC Code 2Q.0102Cq (e).

In addition LOGAN met with representatives of Duke Power to determine whether they would require any special safety equipment or other safety testing prior to beginning operations with the fuel cell. After a review of the fuel cell system, and in consideration of its very minor impact on the campus electrical distribution system, Duke had no objections to the installation plan.

### **Start-up and Commissioning**

The first start occurred on April 24, 2003. Prior to starting the unit the items covered in Figure 6, below, were completed. This week, LOGAN's fuel cell systems technician will continue to test and monitor the unit in accordance with the factory recommended procedures listed in Figure 6 and 7, below. At this time, operations testing and tuning of the fuel cell's electrical and mechanical systems continues to insure smooth and reliable performance. It is anticipated that the unit will be declared operational by May 2, 2003.

Service incidents and facility calls will be reported on the sample Service Call Report form listed below as Figure 8.

An Economic Analysis of the NC A&T RESSDEM project appears in Figure 9 below.

A site map in Figure 10 below indicates the campus location of the fuel cell installation.

### **Installation Check List**

<b>TASK</b>	<b>SIGN</b>	<b>DATE</b>	<b>TIME(hrs)</b>
Batteries Installed			
Stack Installed			
Stack Coolant Installed			
Air Purged from Stack Coolant			
Radiator Coolant Installed			
Air Purged from Radiator Coolant			
J3 Cable Installed			
J3 Cable Wiring Tested			
Inverter Power Cable Installed			
Inverter Power Polarity Correct			
RS 232 /Modem Cable Installed			
DI Solenoid Cable Installed with Diode			
Natural Gas Pipe Installed			
DI Water / Heat Trace Installed			
Drain Tubing Installed			

Figure 6

**Commissioning Check List**

<b>TASK</b>	<b>SIGN</b>	<b>DATE</b>	<b>TIME (hrs)</b>
Controls Powered Up and Communication OK			
SARC Name Correct			
Start-Up Initiated			
Coolant Leak Checked			
Flammable Gas Leak Checked			
Data Logging to Central Computer			
System Run for 8 Hours with No Failures			

Figure 7



<b>SERVICE CALL REPORT</b>	<b>SYSTEM INFORMATION</b>		
<b>System Serial #:</b> _____	<b>Date</b> _____		
<b>Purpose of Service Call:</b> <input type="checkbox"/> Repair <input type="checkbox"/> Maintenance <input type="checkbox"/> ECN    (Check all that apply)			
<b>Date</b> _____	<b>Time</b> _____		
<b>Date/Time shutdown</b> _____			
<b>MAINTENANCE / REPAIR INFORMATION</b>			
<i>Service Tech Name:</i> _____			
<i>Travel Man-hours:</i> _____			
<i>Troubleshooting Manhrs:</i> _____			
<i>Repair Man-hours:</i> _____			
<i>Spare Part Delay Time:</i> _____			
<b>Work</b>			
<i>Performed:</i> _____			
_____			
<i>Technician</i>			
<i>Comments:</i> _____			
_____			
_____			
<b>FAILURE REPORT SUMMARY</b>			
Date	Description of Problem	Rpt #	Initials

Figure 8

## LOGANEnergy Corp.

### FY' 02 RESSDEM NC A&T PEM Fuel Cell Economic Analysis

#### Estimated Project Utility Rates

1) Water (per 1,000 gallons)	\$1.69
2) Electricity (per KWH)	\$0.0651
3) Natural gas ( per MCF)	\$5.25

#### Estimated First Cost

Plug Power 5 kW SU-1	\$65,000
Shipping	\$1,800
Installation electrical	\$4,200
Installation mechanical	\$6,400
Watt Meter, Instrumentation	\$3,150
Site Prep, labor materials	\$925
Technical Supervision	\$8,500
<b>Total</b>	<b>\$89,975</b>

**Assume Five Year Simple Payback \$17,995**

Forecast Operating Expenses	Volume	\$/Hr	\$/ Yr
Natural Gas			
Mcf/hr @ 2.5kW	0.032838	\$0.17	\$1,359
Water			
Gals/Yr	4918		\$8.31

**Add Total Annual Operating Costs \$1,368**

**Total Annual Costs (Ammortization + Expenses) \$19,363**

#### Economic Summary

Forecast Annual kWh	19710	
Annual Cost of Operating Power Plant	\$0.0694	kWh
Credit Annual Thermal Recovery	-0.016489	kWh
Project Net Operating Cost	\$0.0529	kWh
Amount Available for Financing	\$0.0122	kWh
Add 5 Yr Ammortization Cost / kWh	\$0.9130	kWh

**Current Demo Program Cost Assuming 5 Yr Simple Payback \$0.9824 kWh**

**\*\*NOTE\*\*Does not include allowance for cell stack life cycle costs or service**

**over 5 year economic senario**

**Figure 9**



## Project Contacts

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Figure 10



NC A&T Fuel Cell Installation Site,  
Building 10, Campbell Hall